

# Creating an Artificial Coaching Engine for Multi-domain Conversational Coaches in eHealth Applications

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## ABSTRACT

In this paper the concept of an Artificial Coaching Engine is described, which is being developed for a state-of-the-art multi-agent multi-domain coaching application. The engine will fulfil three main functions in this application. First, it will serve as a knowledge base and user model, representing user, context, and artificial coach information. Second, it will represent and select the coaching goals that the coaches will coach towards. Third, it will select the most suitable coaching strategies for reaching the selected coaching goals. Following the description of the concept, we will discuss our approach and the challenges in the development of the Artificial Coaching Engine.

## CCS CONCEPTS

• **Human-centered computing** → *HCI theory, concepts and models*; • **Computing methodologies** → *Knowledge representation and reasoning*; • **Social and professional topics** → User characteristics;

## KEYWORDS

Artificial coaching; health behaviour change; lifestyle coaching; user modelling; coaching goals and strategies; eHealth; tailoring

### ACM Reference Format:

Tessa Beinema, Harm op den Akker, and Hermie Hermens. 2018. Creating an Artificial Coaching Engine for Multi-domain Conversational Coaches in eHealth Applications. In *Proceedings of ACM Workshop on Intelligent Conversation Agents in Home and Geriatric Care Applications (ICA-HoGeCa2018)*.

## 1 INTRODUCTION

The average age of the World's population is increasing. In a 2017 report, the United Nations reports the number of persons aged 60 or above is expected to more than double by 2050 and even triple by 2100 [8]. For Europe the expected increase by 2050 will be from 25% of the population to 35%.

With the rising average age of the population there is also an increasing percentage of the population that suffers from noncommunicable diseases (NCDs) or chronic diseases. The main types of such diseases are cardiovascular diseases, cancers, chronic respiratory diseases and diabetes [6], but dementia and depression are also common. While NCDs are responsible for 70% of all deaths globally each year (that is, 40 million people), the length of time that people suffer from them is also very long and puts a large drain on health care resources and manpower.

An effective approach for the prevention and control of NCDs is reducing risk factors in multiple domains. For example, for cardiovascular diseases and diabetes, this can involve the adoption of a healthy diet and healthy exercise habits. More generally, adopting a healthier lifestyle can delay NCDs and improve quality of life. While the coaching approach that is most suitable varies between target groups, research has shown that health coaching by health care professionals improves the management of chronic diseases [3]. Given the size of the challenge, the implementation of health coaching by human coaches for a large target audience requires more manpower and resources from the health sector.

One solution for the limited availability of human coaches can be found in eHealth applications for personalised coaching, or e-coaching systems. These systems can be used to help people with adopting a healthier lifestyle. Through coaching, users can be informed, assisted and empowered.

### 1.1 E-coaching systems

We adopt the definition by Kamphorst as a description of e-coaching systems:

*An e-coaching system is a set of computerized components that constitutes an artificial entity that can observe, reason about, learn from and predict a user's behaviours, in context and over time, and that engages proactively in an ongoing collaborative conversation with the user in order to aid planning and promote effective goal striving through the use of persuasive techniques [2].*

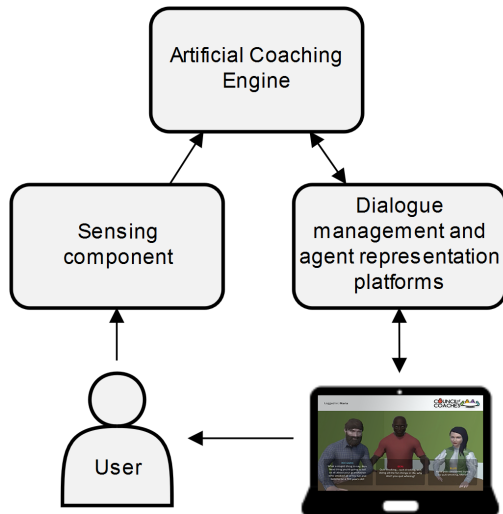
Within e-coaching, there are many applications that focus on a single domain or target group. Examples of domains include: healthy eating, physical activity, diabetes management or mental health. Examples of target groups are: the elderly, chronic pain patients or obese children. In recent years there is also an increase of applications that have the focus on a combination of two domains, for example, healthy eating and physical activity. However, since the risk factors for NCDs can be found across multiple domains, we believe that a holistic approach to healthy living is crucial and thus e-coaching should also focus on aiding the user in multiple domains.

Apart from the coaching domain and target audience, other important aspects for e-coaching systems that focus on health promotion are that they should be interactive, interoperable, personally engaging, contextually tailored and that they should be suitable to deliver to mass audiences [4].

An application in development that will incorporate the aspects mentioned above is the Council of Coaches [5]. The Council of Coaches will be a state-of-the-art multi-agent e-coaching application that will combine holistic behaviour analysis, smart adaptive coaching, dialogue management (using the DGEP platform [1]), and realistic embodied conversational agents (using the GRETA/VIB platform [7] and ASAP platform [9]) to aid its users in obtaining a healthier lifestyle. The three initial target groups will be people with Age Related Impairments, Type 2 Diabetes, or Chronic Pain.

The Council of Coaches application will involve multiple embodied conversational coaches, each with their own expertise. The presence of multiple coaches allows for multi-coach strategies, for example, a coach explaining something to another coach to teach the user or ‘good coach - bad coach’. There are many interesting facets to the project, and in this paper we focus on one of them: the development of the Artificial Coaching Engine.

## 2 THE ARTIFICIAL COACHING ENGINE



**Figure 1: The placement of the Artificial Coaching Engine in the Council of Coaches system.**

The Artificial Coaching Engine will fulfil the role of the intelligent coaching component in the Council of Coaches system. As can be seen in Figure 1 it has a central place in the system connecting the components that are responsible for gathering data and those generating the embodied conversational agents, the dialogues and their behaviour. Taking this role in the system, there are three main functions that the Artificial Coaching Engine will fulfil, namely, as a knowledge base, as a goal selector and as a strategy selector. A schematic overview of how these elements influence each other can be found in Figure 2, and an overview of process within the Artificial Coaching Engine can be found in Figure 3.

### 2.1 Knowledge base

The first function of the Artificial Coaching Engine is to serve as a knowledge base, and it will contain three types of knowledge

(see Figure 2). Dynamic knowledge relates to knowledge that can quickly change, such as, for example, information available about the current user. Semi-static knowledge relates to knowledge that is quite static, but that might be updated, such as, for example, knowledge about what a healthy diet entails. Static knowledge relates to knowledge that is not expected to change, such as, for example, a user’s brother is someone that shares the same parents. The represented information will be leveraged by the coaching modules in the coaching engine as well as by multiple components of the overall system for tailoring their output.

The representation of the user in the coaching engine will contain information from two main sources. Firstly, information on the user’s short-term and long-term behaviours will be represented which is gathered by the system’s sensing component (for example, physical activity or facial expressions). The sensing component will also detect changes in behaviour and it will provide context information. Secondly, information obtained through the user’s interaction with the system will be represented.

The representation of the coaches includes predefined knowledge for each coach on their personalities, domains, mannerisms, backstories, etc. It will also include a representation of the coaching goals and available coaching strategies for each coach (which will be elaborated on in the next two subsections). Within the coaching engine, each coach has an individual knowledge base, which contains the knowledge necessary to coach in their domain.

### 2.2 Automatic goal selection

The second function of the Artificial Coaching Engine is to select the coaching goals for the coaches. For an e-coaching system to coach people, it should be clear what the goal of the provided coaching is. That is, there should be (intermediary) goals which are aimed for when interacting with the user. Examples can be to achieve a change in behaviour, the assimilation of transferred information, or to help a user feel more empowered.

In the Council of Coaches system there are multiple embodied conversational coaches, who will all coach in their own domain. As can be seen in Figure 2, each of the coaches will have a personal implementation of a shared goal model. That is, the model is the same, but the priorities for the goals may be different for different coaches. In the goal model it is represented what each goal is and how the goals can be related to each other. Each goal must at least include the domain or domains to which it belongs, what the prerequisites are for the goal to be allowed to be set, and if it has been completed or if it perhaps is irrelevant for the current user. The task of the automatic goal selector is to decide which goal is most relevant to pursue for the coach based on the available knowledge.

### 2.3 Tailored coaching strategies

The third function of the Artificial Coaching Engine is to select the coaching strategies that are most suitable for reaching a coaching goal (again, see Figure 2). Once a goal has been selected for a coach, a coaching strategy can guide that coach’s interactions with the user to reach that goal. Each coach will have a set of coaching strategies available, and, while that set might partly be the same as

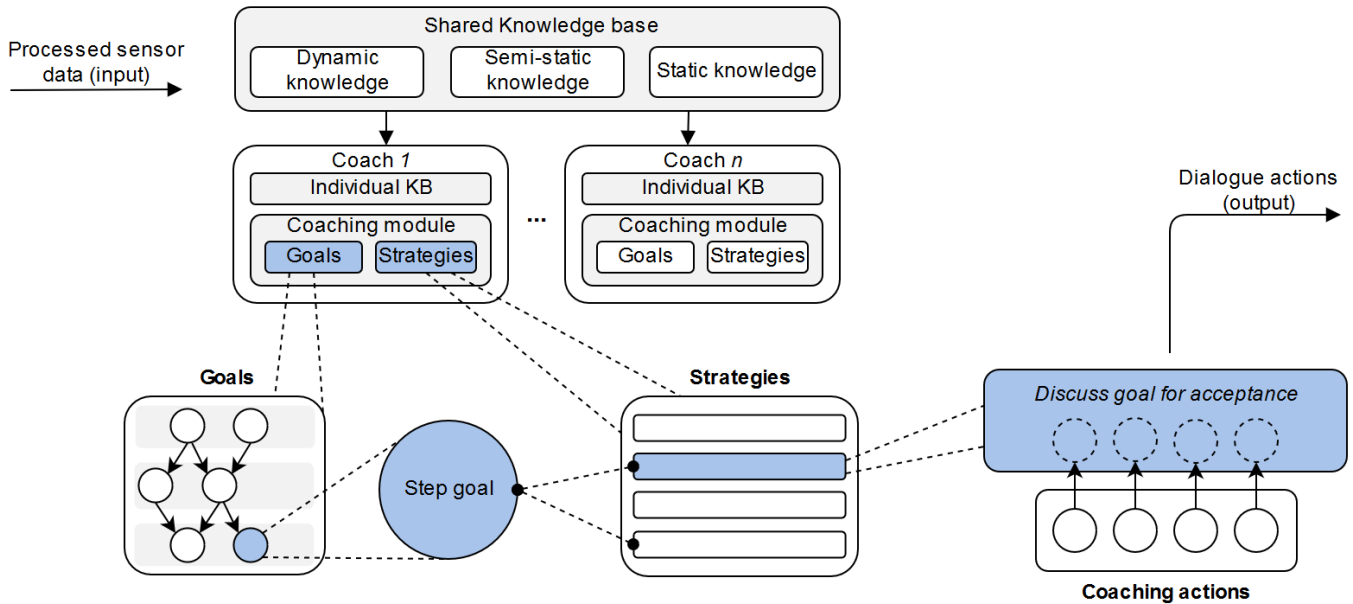


Figure 2: A schematic representation of the elements in the Artificial Coaching Engine and how these interact to fulfil each of the coaching engine's three main functions.



Figure 3: A schematic representation of the process in the Artificial Coaching Engine.

for other coaches, the strategies that are available to a coach are selected to be suitable for that coach's domain.

The most suitable strategy for reaching a goal will be determined based on the available information about the user. For example, if the goal is to inform a user about the importance of physical exercise, for a well-informed user a coach might ask that user what they know, so that they can correct flaws in their knowledge, while for a very uncertain user the strategy might involve dropping subtle hints about the topic and giving compliments.

The definition of coaching strategies starts by designing strategies using literature on behaviour change and e-coaching, and the expertise of domain experts. These strategies then need to be modelled to create a technical representation. The modelled strategies should contain a set of defined prerequisites and clearly structured contents. In the end, the selected strategy (or strategies if there are multiple suitable candidates) is sent to the dialogue management component and agent representation component to guide the coach's dialogue actions and behaviour.

## 2.4 Research questions

The development of the Artificial Coaching Engine brings a number of research questions with it. The main questions are:

- What is the knowledge about the user and their context that needs to be available to be able to coach?
- How do we represent this knowledge?
- How do we represent and how do we select the coaching goals?
- How do we handle different goals for different coaches?
- Which coaching strategies are relevant for the coaching domains?
- How do we represent and select the coaching strategies?

## 3 APPROACH AND CHALLENGES

The realisation of the Artificial Coaching Engine brings with it many challenges. In the following subsections we describe our approach for the development of the engine's three main functions and we discuss the main challenges in that process. We also discuss evaluation, which can be challenging for a component in an e-coaching system that aims for behaviour change.

### 3.1 Knowledge modelling

As mentioned previously, the knowledge base will contain a representation of information on the user and a representation of the coaches. The design of the user model will be based on observations from the literature on behaviour change, the behaviours

and behaviour changes measured by the sensing platform and the information resulting from interactions with the user.

The first step will be to create a framework that models the aspects of a user's physical state, mental state, and context that influence behaviour change processes. Initially the models in this framework will involve the, often abstract, concepts that can be deduced from theories about behaviour change. While theories of behaviour change describe the underlying processes of behaviour change in persons, we will use these theories to infer concepts that can be build up from the data that we obtain through sensors and interaction. We will make these concepts more concrete by mapping them to the possible means of measurement. The final implementation of the knowledge for the system will be refined from this set of measurable features based on the requirements resulting from the prerequisites of the sets of goals and strategies that the coaches will have.

The representation of the coaches will be based on character designs and implemented following the requirements of the system's agent representation component. That is, for example, personality and mannerisms will be implemented in such a way that they can be used in the generation of the coaches' behaviours and adjustment of their dialogue actions. We discuss the representation of the goals and strategies, which are a part of the coaches as well, in the following two subsections.

### 3.2 Automatic goal selection

The construction of the automatic goal selection module brings two main challenges. The first is the modelling of the goals. A single goal will have prerequisites and can be a super- and or subgoal of other goals. But, and especially when dealing with multiple coaches that all have their own domains such as in the Council of Coaches system, there is no obvious hierarchy in which goals from multiple domains are already related to each other. For example, a goal contributing to a relaxed and happy user might take some effort to balance with goals on physical exercise or dieting.

The second challenge involves the selection of goals. When presented with a hierarchical network, one might envision a manner of going through that network and selecting the next goals on the basis of being relevant or 'to be completed'. Again, the introduction of multiple coaches with multiple domains makes this more challenging. If in the system each coach has its own representation of the goal model, this means that the goals that are selected for the coaches should be goals that can coexist.

### 3.3 Strategy definition and representation

Once a coaching goal has been selected, the coach or a combination of coaches can employ a coaching strategy to reach that goal. The development of these strategies brings with it some design choices. To start, what is, for example, the 'duration' of a coaching strategy? That is, can a strategy for coaching the user to move more involve simply telling the user 'You need to move more!', or is it a longer conversation where the coach tells the user how much they have been moving in the past few weeks, what their new step target is, why this is important, why they can do it and helps them plan to reach the behaviour?

Once a decision on the duration of strategies has been made, the second step is to define informally what the various coaching strategies are that are valid options for reaching the coaching goals. Of course there can be multiple strategies that are suitable for reaching those goals, depending on the knowledge about the user, the coaches available and other goals.

After the informal definition of the coaching strategies, they should be modelled so that this technical representation can be used to filter the possible dialogue actions. As can be seen in Figure 2 a strategy can be seen as a template that can be filled in by certain coaching actions. These coaching actions in turn can consist of one or more dialogue actions, which can also be responses to replies from the user.

The challenge in creating the coaching strategies lies in not only developing them for single coaches, but also for a joint coaching approach between two or more coaches at the same time. An example could be the 'good coach, bad coach'-strategy, in which one coach might take on a very empathic role while the other might enquire why the user did, for example, not reach their step goal for that day.

### 3.4 Evaluation

Another challenge in the development of the Artificial Coaching Engine is its evaluation, both for intermediate versions and for the final version of the engine. That is, the aim for the Artificial Coaching Engine is to select strategies that can be deployed to change the user's behaviour. Since behaviour change is an effect that can only be measured after a longer period of use, this also means that the possibility exists that the user's (lack of) behaviour change might have been caused by external factors. While measuring behaviour change is challenging in itself, in addition to the external factors, the influence of the components layered between the coaching engine and the user, such as the dialogue management and agent representation platforms, should also be taken into account.

One possible approach for evaluation could be to artificially generate users, and to, for these users, output the selected goals and strategies. This output can then be evaluated on whether it indeed is the response the system should generate.

## 4 CONCLUSION

In this paper we described the concept of the Artificial Coaching Engine. We have illustrated its functions and the challenges that must be faced in the development process. In future research we will describe how we have tackled these challenges and report on the implementation of the Artificial Coaching Engine itself and its components.

## ACKNOWLEDGMENTS

The Council of Coaches project, of which this research is a part, has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement #769553. This result only reflects the author's view and the EU is not responsible for any use that may be made of the information it contains.

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